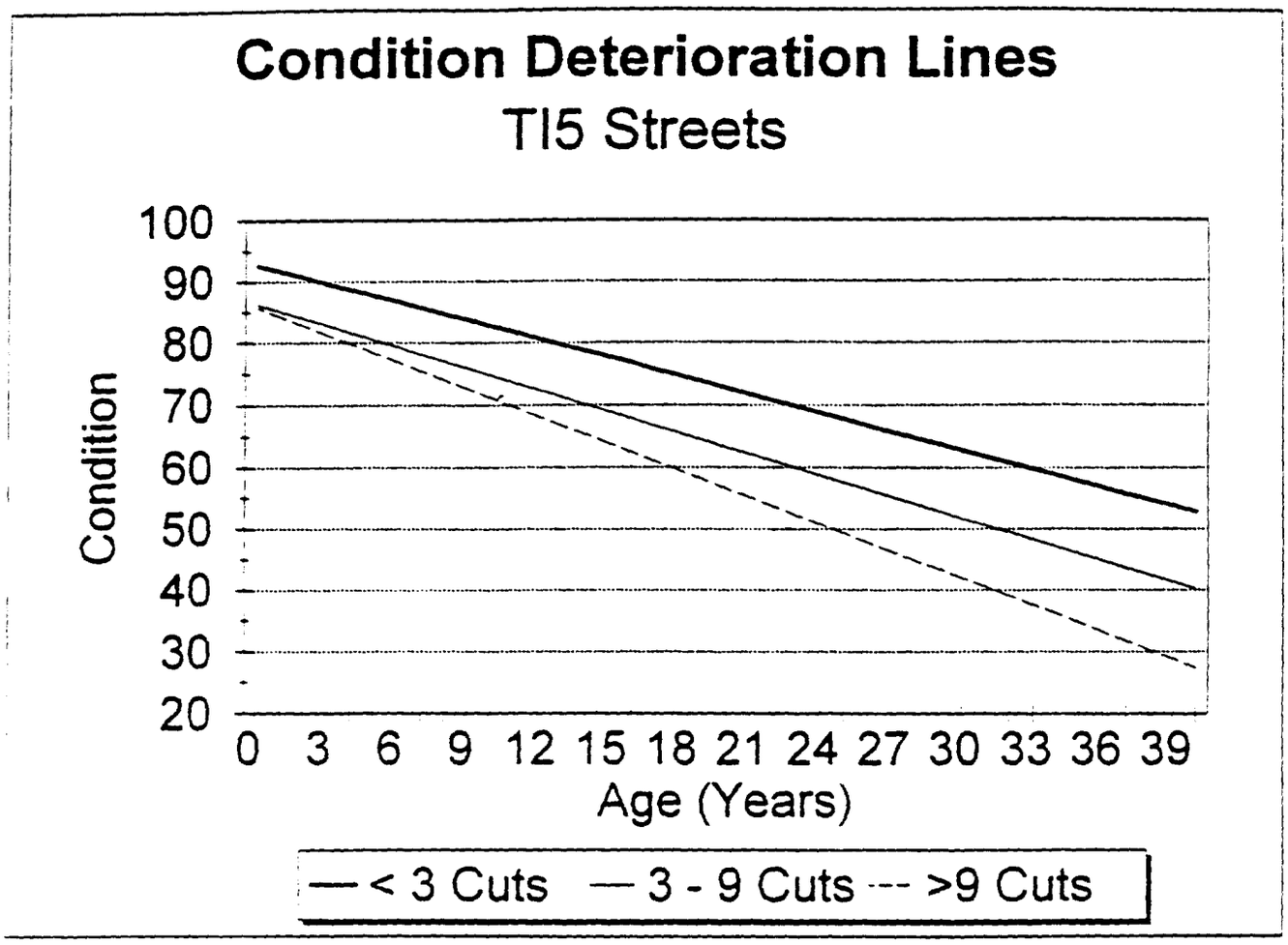
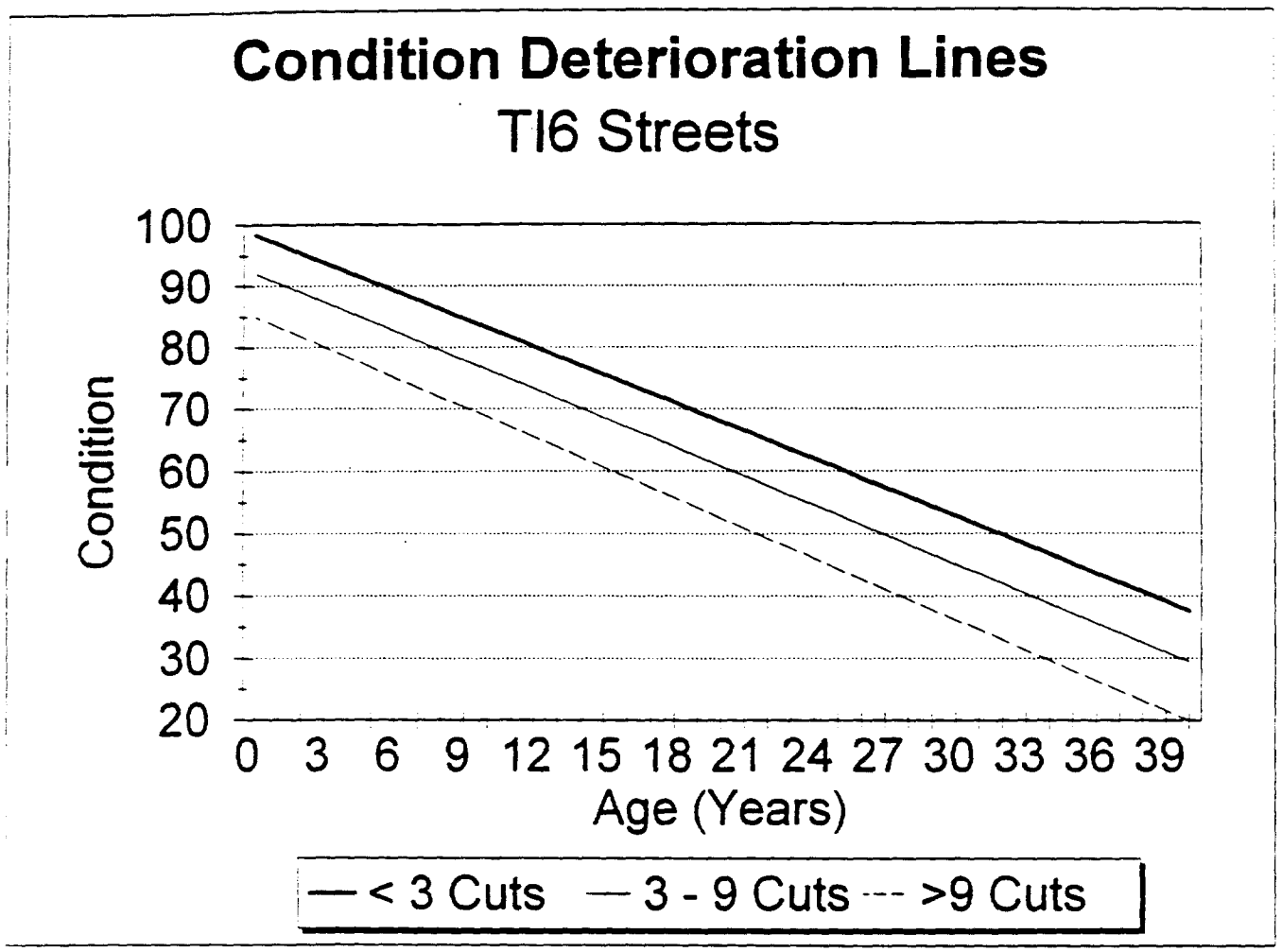
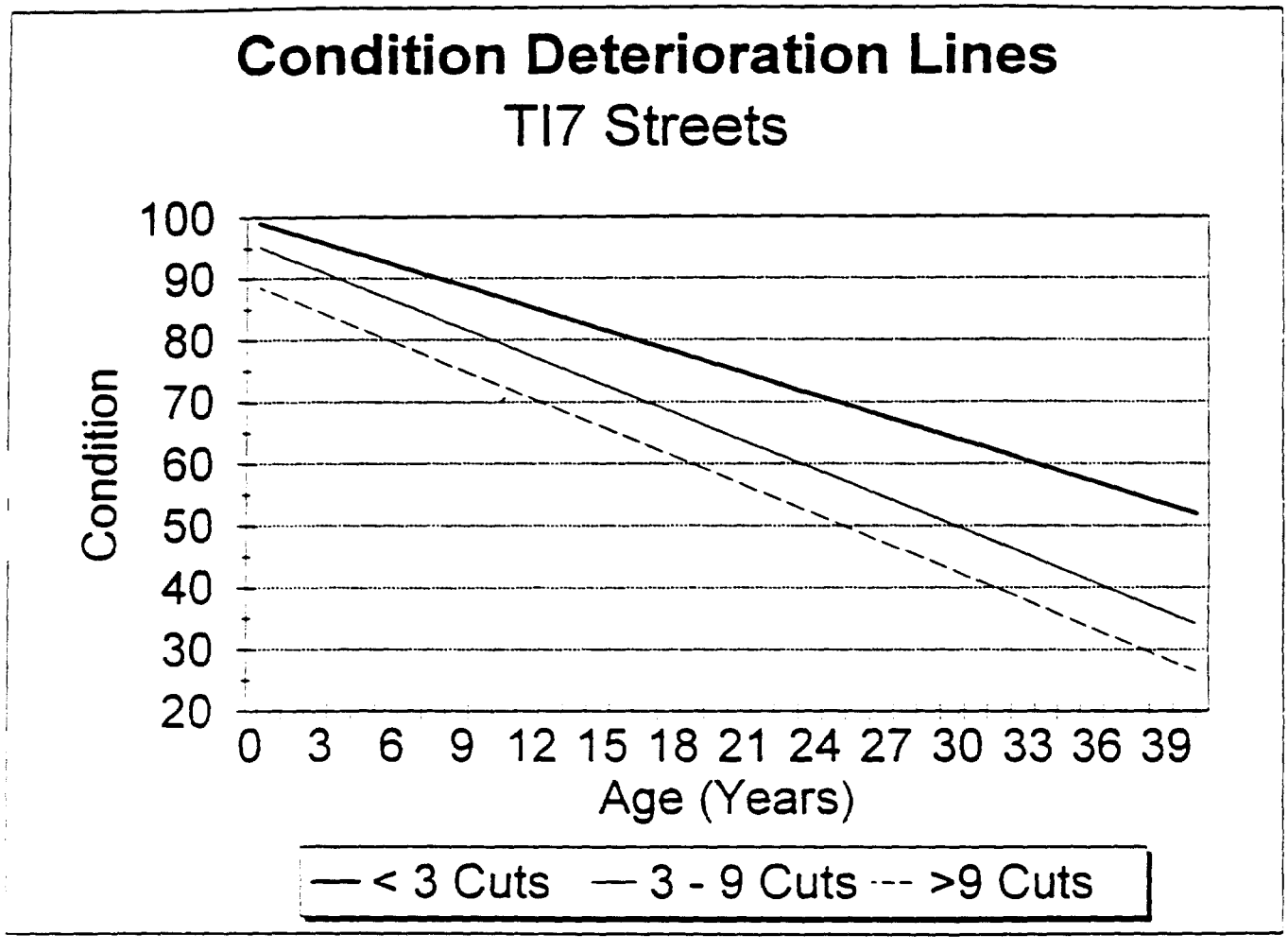
APPENDIX I

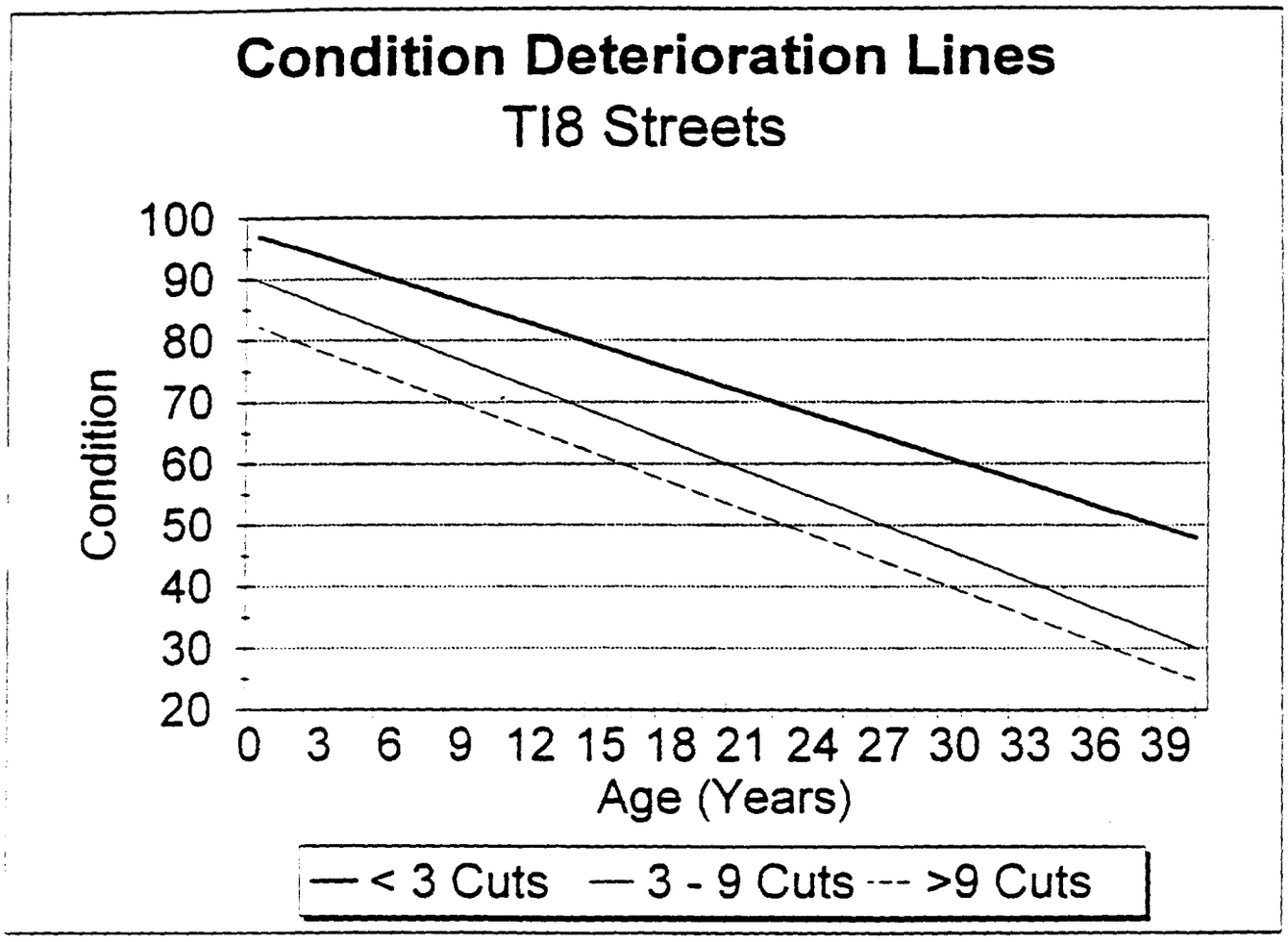
Regression Curves

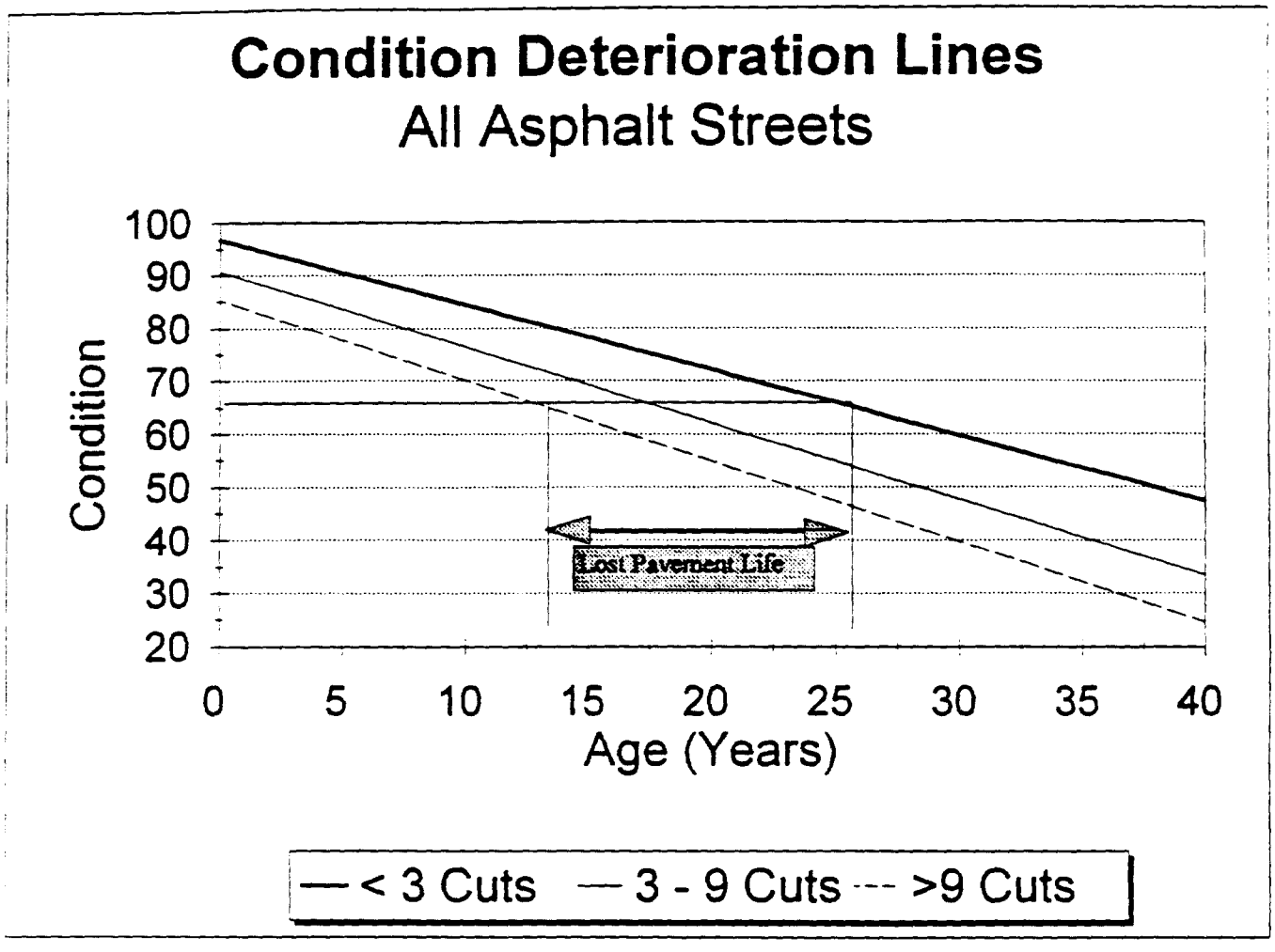
TI5 Asphalt Streets
TI6 Asphalt Streets
TI7 Asphalt Streets
TI8 Asphalt Streets
All Asphalt Streets
All Concrete Streets

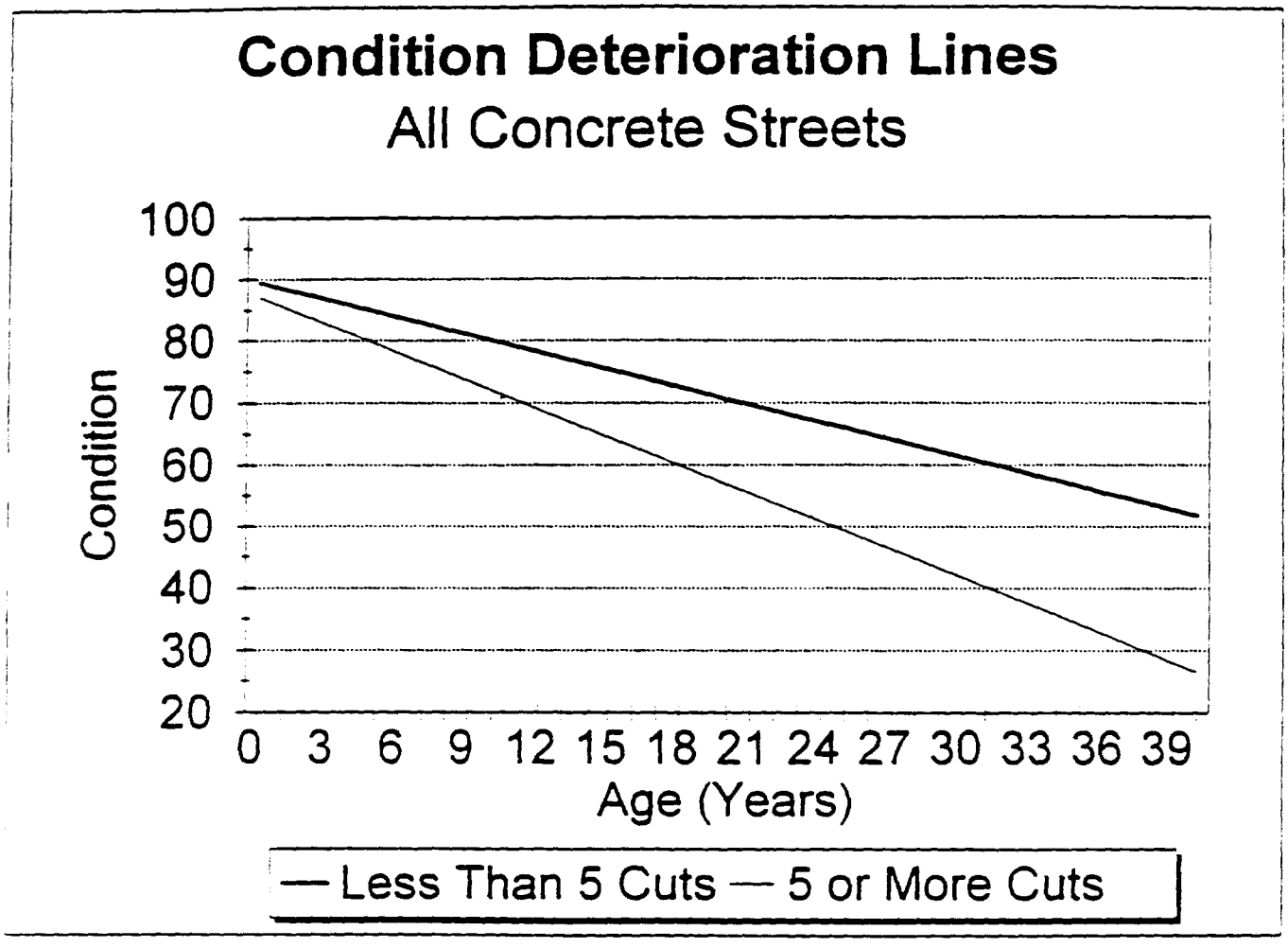

Condition Deterioration Lines
TI5 Streets
Condition
100
90
80
70
60
50
40
30
20
0 3 6 9 12 15 18 21 24 27 30 33 36 39
Age (Years)
— < 3 Cuts
— 3 - 9 Cuts
--- >9 Cuts


Condition Deterioration Lines
TI6 Streets
100
90
80
70
60
50
40
30
20
Condition
0 3 6 9 12 15 18 21 24 27 30 33 36 39
Age (Years)
— < 3 Cuts
— 3 - 9 Cuts
--- >9 Cuts


Condition Deterioration Lines
TI7 Streets
100
90
80
70
60
50
40
30
20
Condition
0 3 6 9 12 15 18 21 24 27 30 33 36 39
Age (Years)
— < 3 Cuts
— 3 - 9 Cuts
--- >9 Cuts


Condition Deterioration Lines
TI8 Streets
Condition
100
90
80
70
60
50
40
30
20
0 3 6 9 12 15 18 21 24 27 30 33 36 39
Age (Years)
— < 3 Cuts
— 3 - 9 Cuts
--- >9 Cuts


Condition Deterioration Lines
All Asphalt Streets
Condition
100
90
80
70
60
50
40
30
20
0
5
10
15
20
25
30
35
40
Age (Years)
Lost Pavement Life
< 3 Cuts
3 - 9 Cuts
>9 Cuts


Condition Deterioration Lines
All Concrete Streets
100
90
80
70
60
50
40
30
20
Condition
0 3 6 9 12 15 18 21 24 27 30 33 36 39
Age (Years)
— Less Than 5 Cuts — 5 or More Cuts

APPENDIX II

Table of Regression Results

Scatter Diagrams and Regression Lines

Summary of Linear Regression Results

	TI	Type	a	b	N	C
Few			92.6622	-0.99869	1375	0.44
Some	5	Asphalt	86.2193	-1.14950	1162	0.51
Many			85.6693	-1.45735	1007	0.58
Few			98.3662	-1.51900	306	0.56
Some	6	Asphalt	92.0506	-1.56683	283	0.56
Many			84.9040	-1.62470	187	0.61
Few			99.0357	-1.18153	245	0.50
Some	7	Asphalt	95.1678	-1.52507	183	0.59
Many			88.5982	-1.55190	103	0.63
Few			97.1029	-1.23308	729	0.39
Some	8	Asphalt	89.7949	-1.49363	417	0.46
Many			82.1770	-1.43288	167	0.60
Few	All	Concrete	89.4635	-0.94371	81	0.44
Many			87.1011	-1.51426	47	0.71

TI: Traffic Index

Type: Type of Pavement Surface

a: Linear Regression Constant " $Y = a X + b$ "

b: Linear Regression Independent variable Coefficient

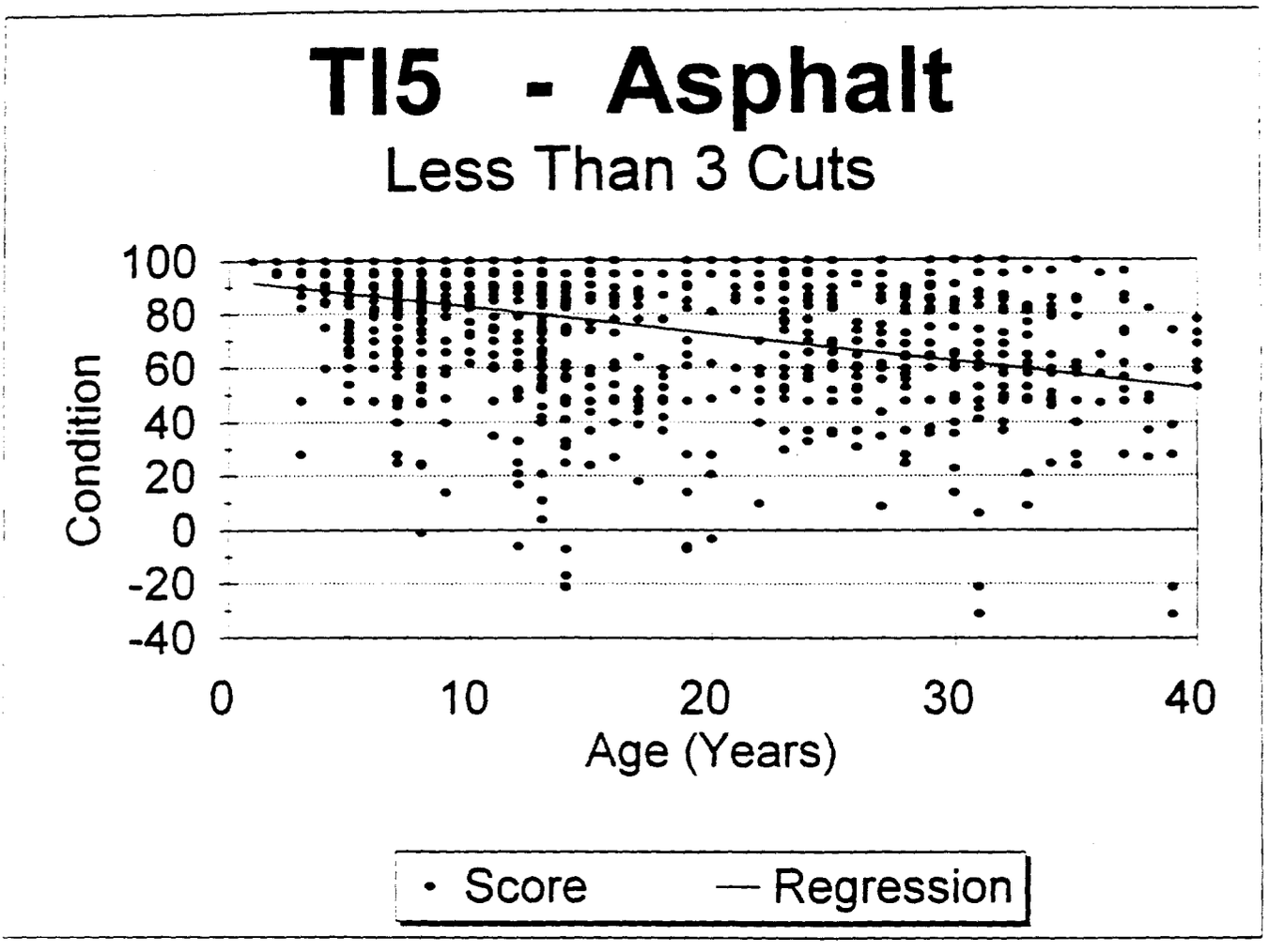
N: Number of Data Points Used in Regression Analysis

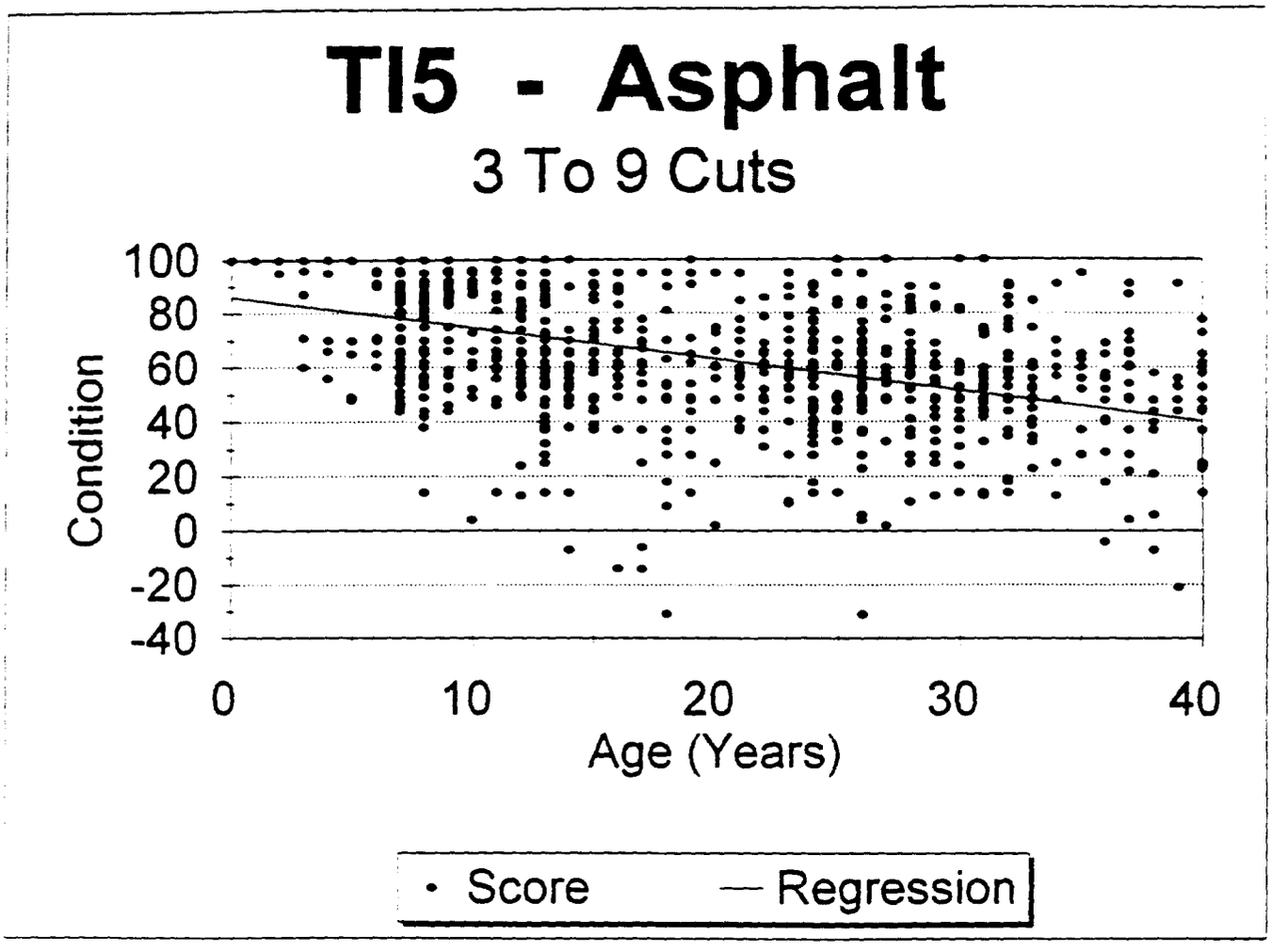
C: Correlation Coefficient

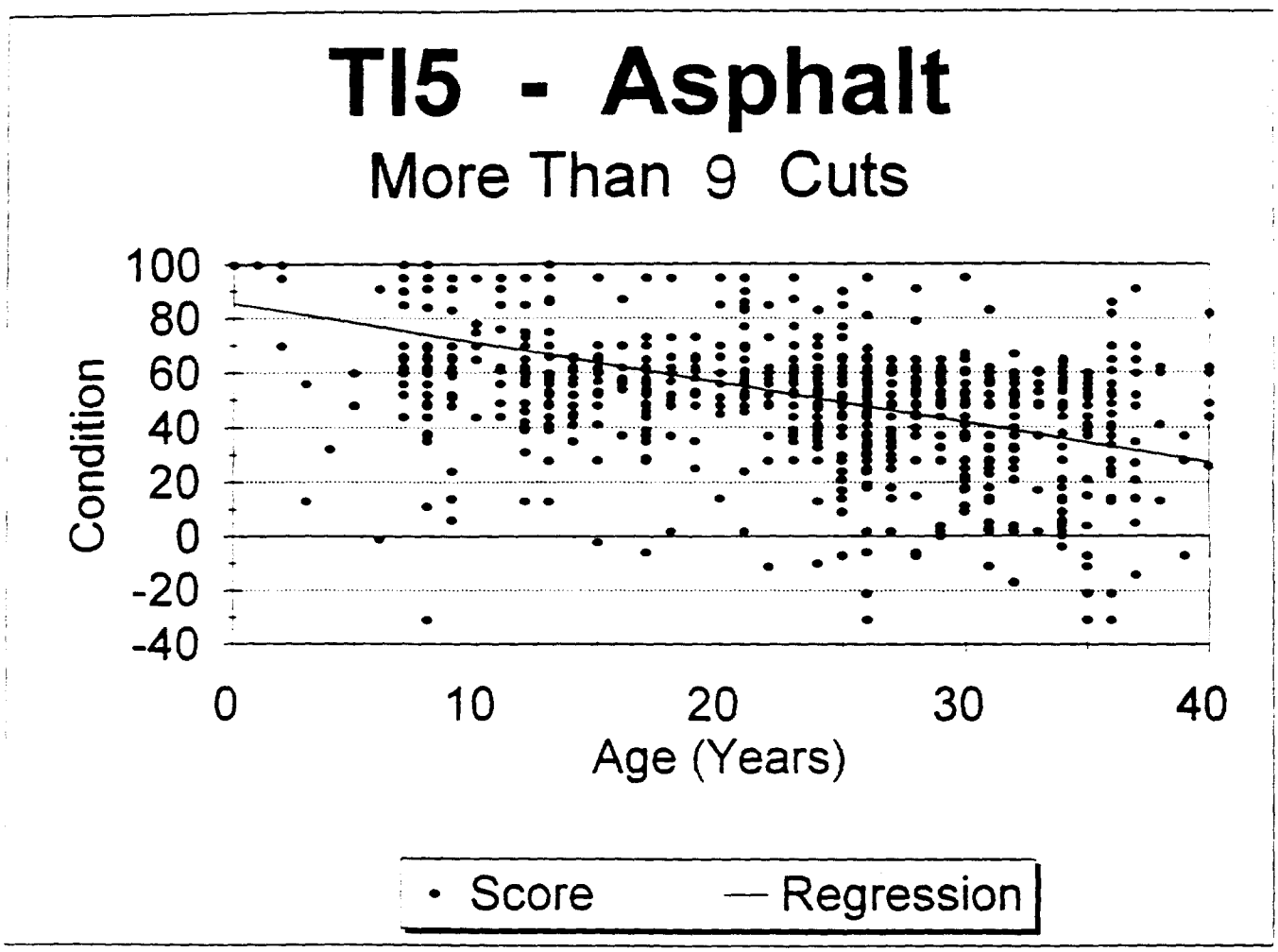
Few: Less than 3 cuts per section for asphalt pavements and less than 5 cuts per section for concrete pavements.

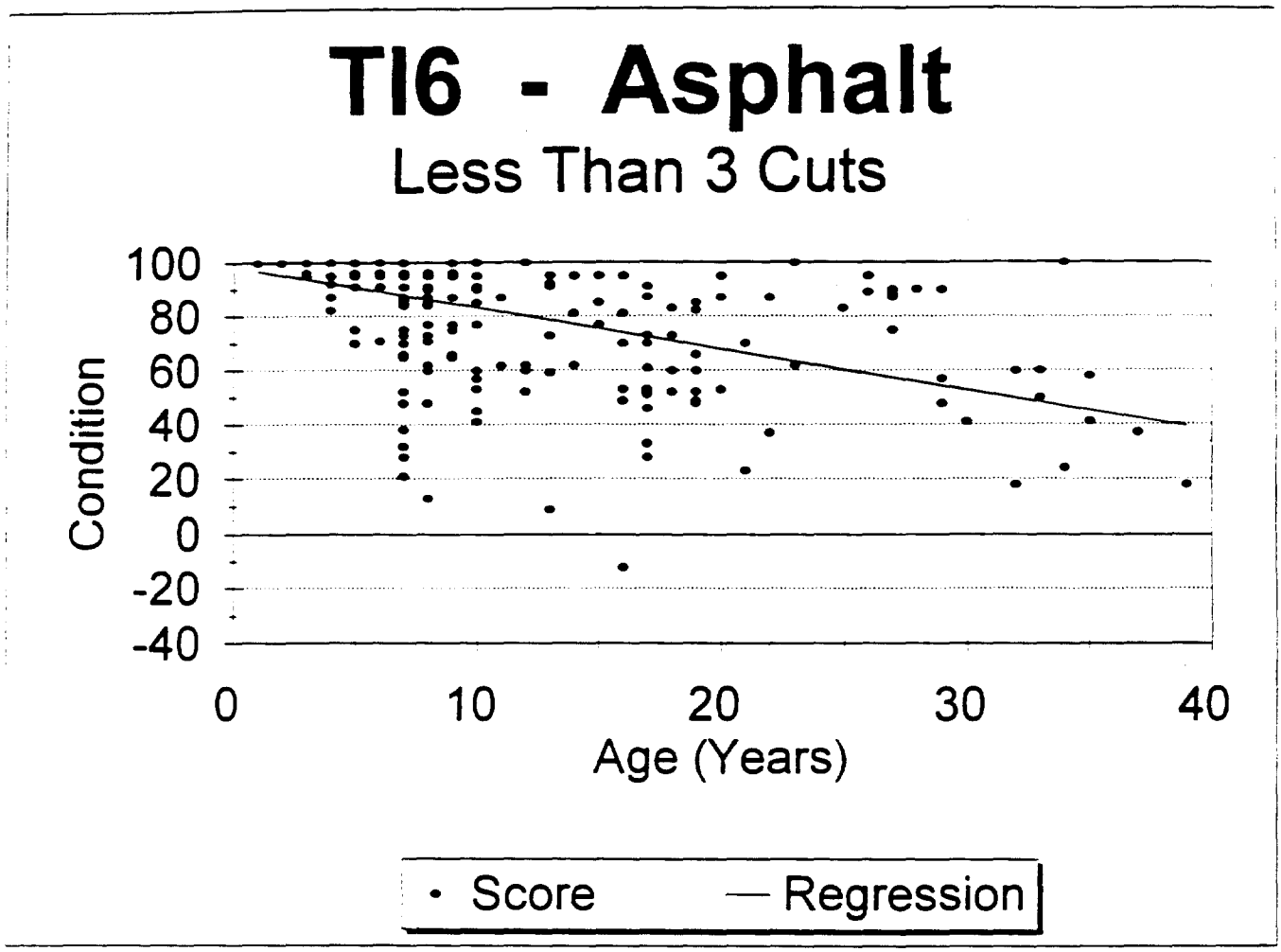
Some: Between 3 and 9 cuts per section for asphalt pavements.

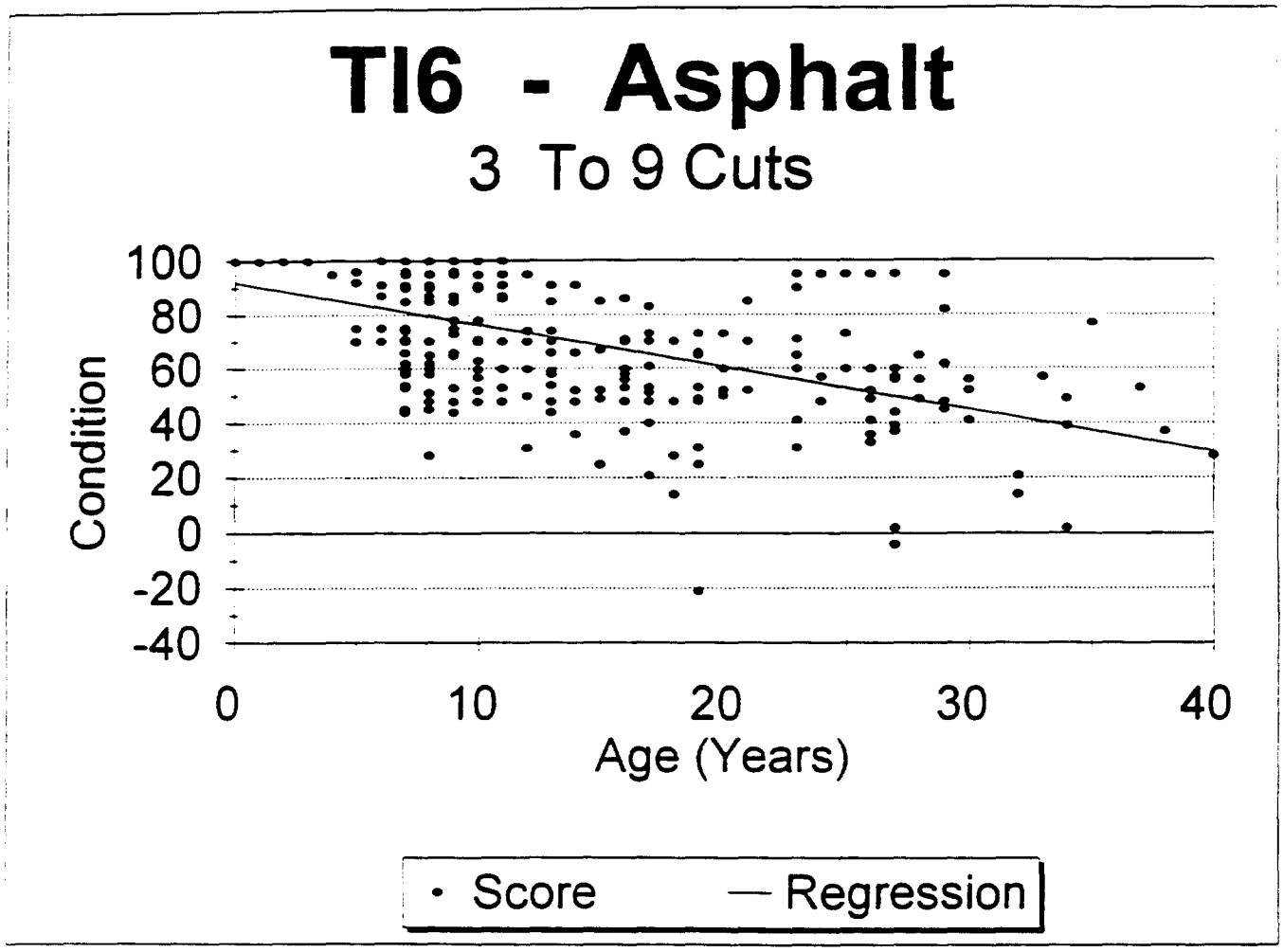
Many: 10 or more cuts per section for asphalt pavements and 5 or more cuts per section for concrete pavements.

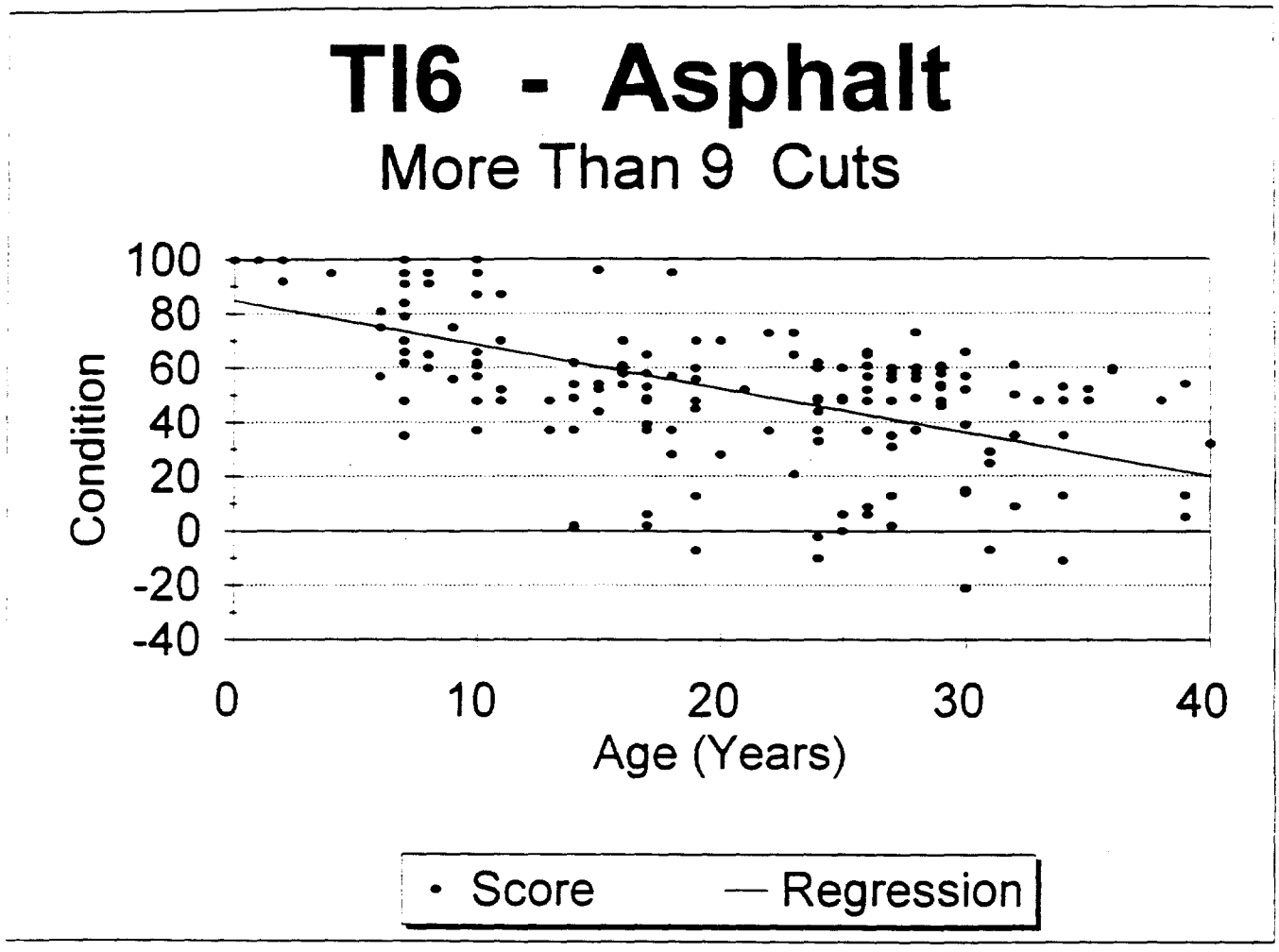

TI5 - Asphalt
Less Than 3 Cuts
Condition
100
80
60
40
20
0
-20
-40
0
10
20
30
40
Age (Years)
Score
Regression

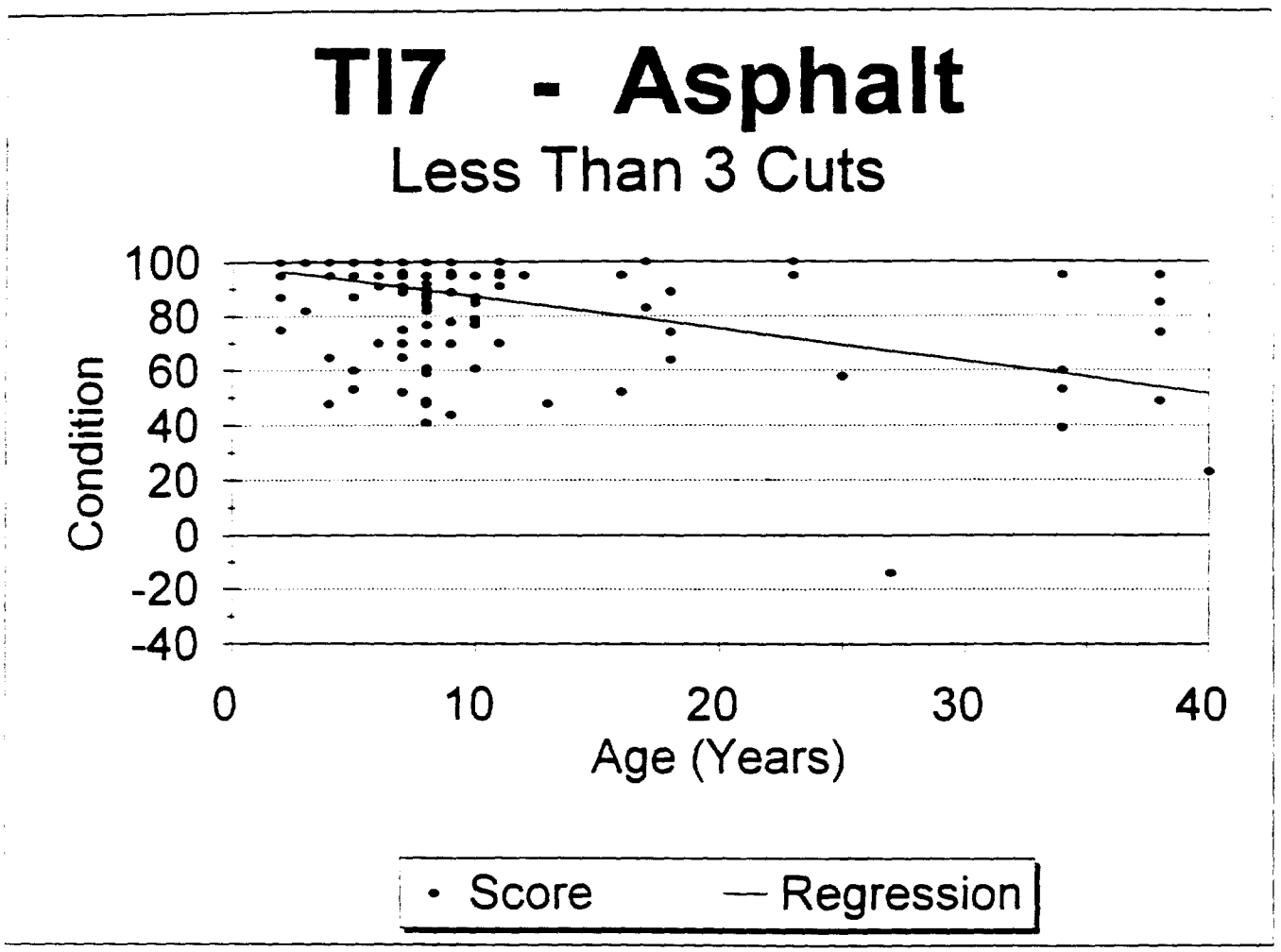

TI5 - Asphalt
3 To 9 Cuts
Condition
100
80
60
40
20
0
-20
-40
0
10
20
30
40
Age (Years)
Score
Regression

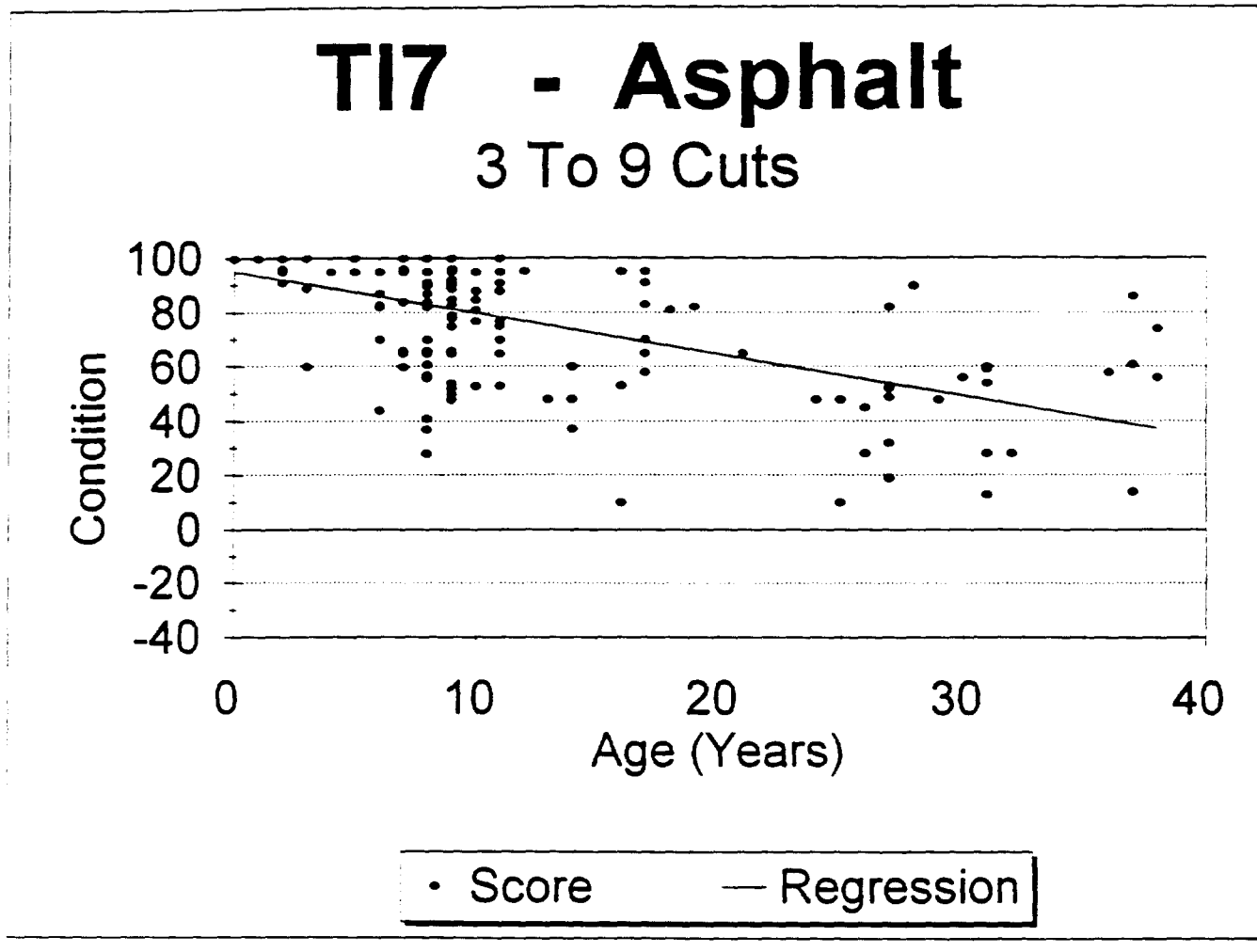

TI5 - Asphalt
More Than 9 Cuts
Condition
100
80
60
40
20
0
-20
-40
0
10
20
30
40
Age (Years)
Score
Regression

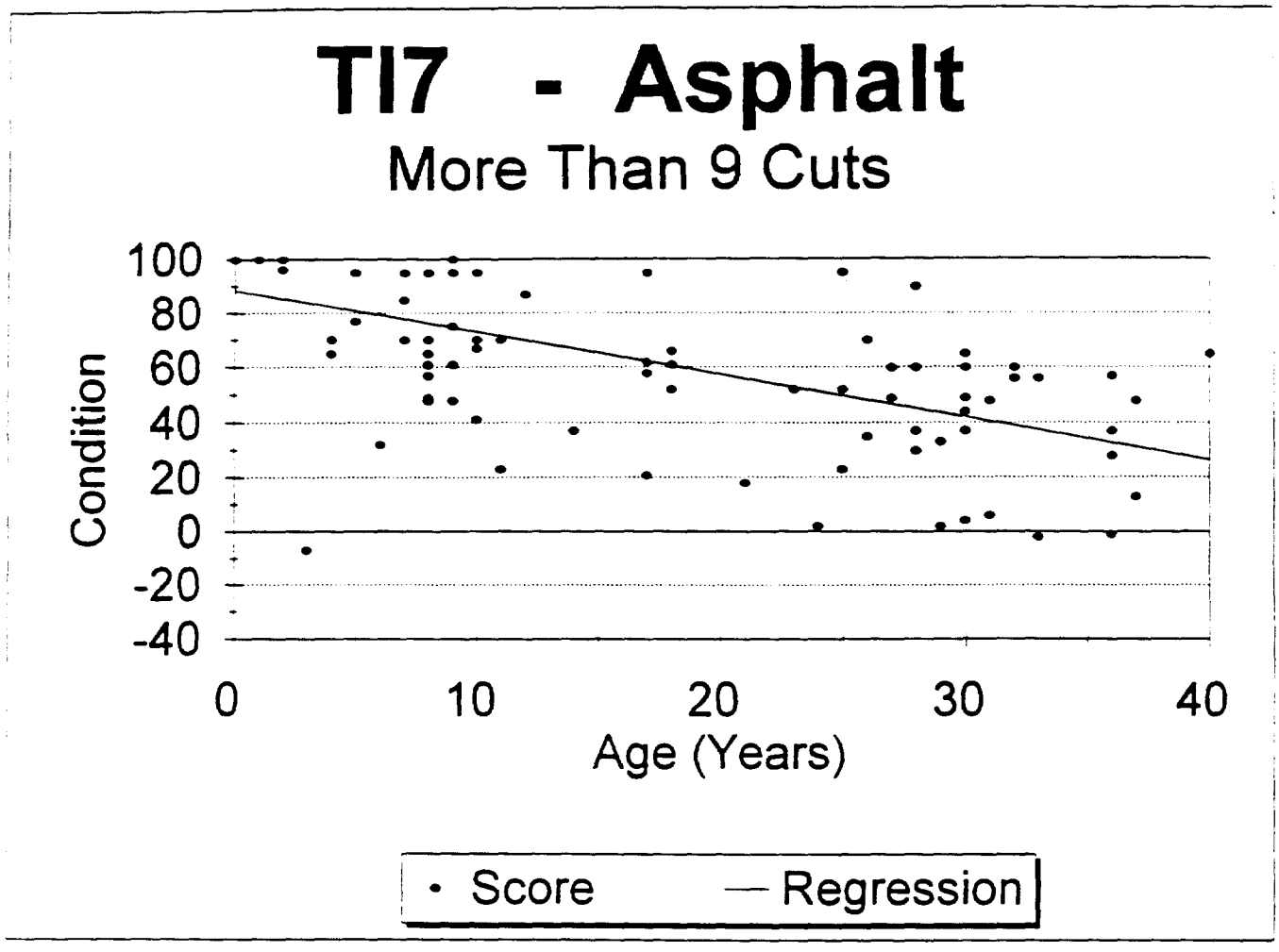

TI6 - Asphalt
Less Than 3 Cuts
Condition
100
80
60
40
20
0
-20
-40
0
10
20
30
40
Age (Years)
Score
Regression

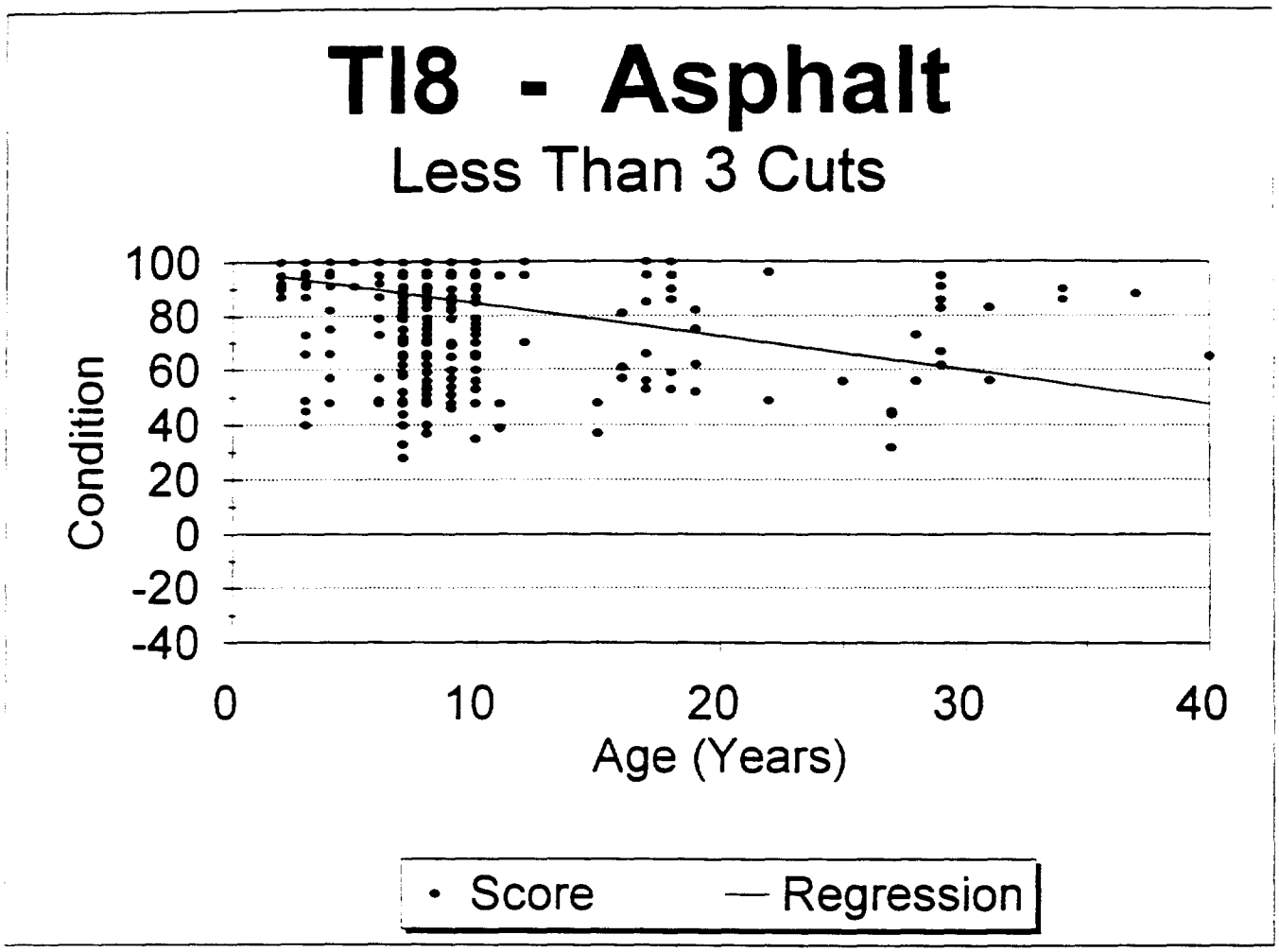

TI6 - Asphalt
3 To 9 Cuts
100
80
60
40
20
0
-20
-40
Condition
0
10
20
30
40
Age (Years)
Score
Regression

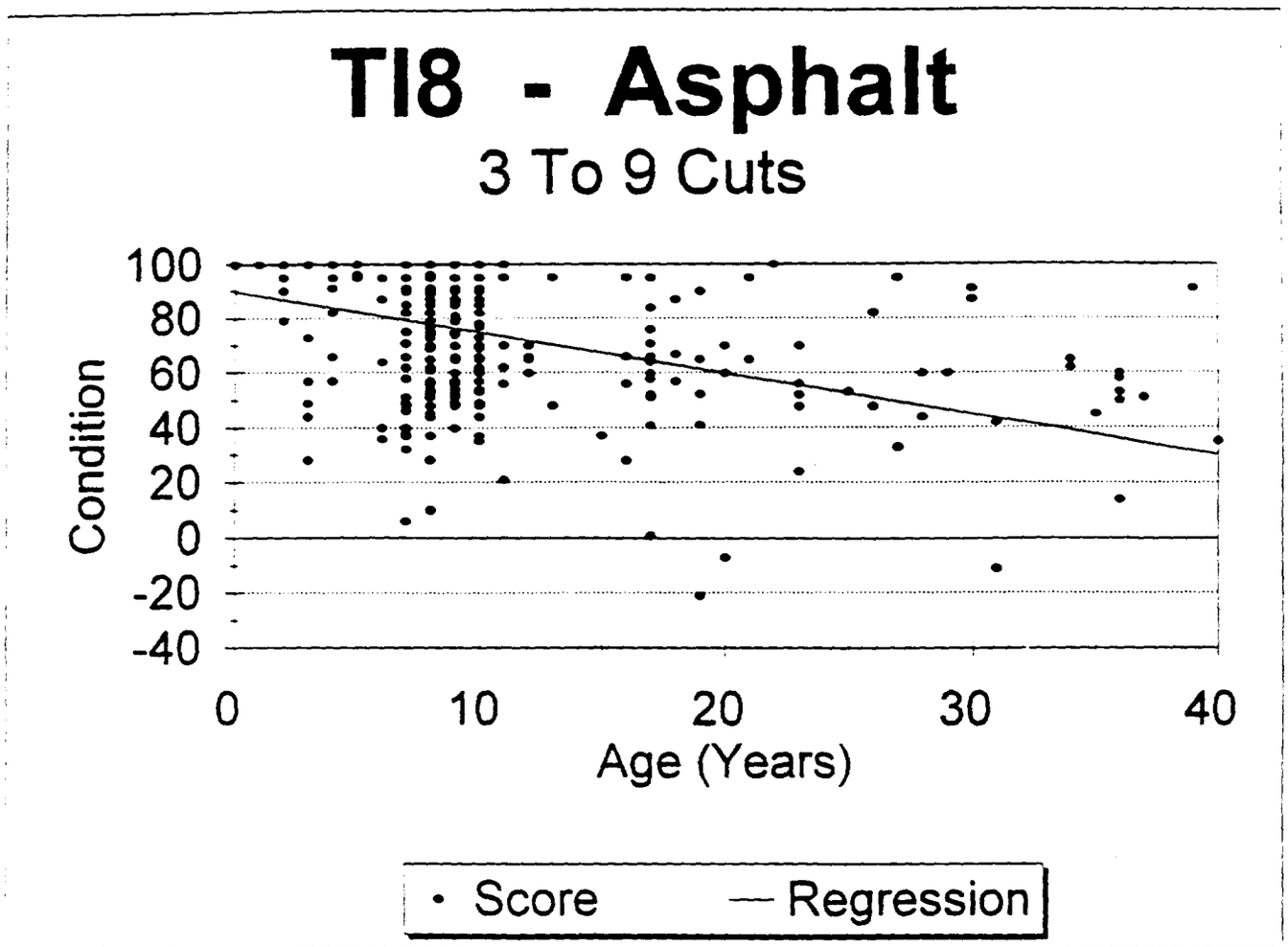

TI6 - Asphalt
More Than 9 Cuts
100
80
60
40
20
0
-20
-40
Condition
0
10
20
30
40
Age (Years)
Score
Regression

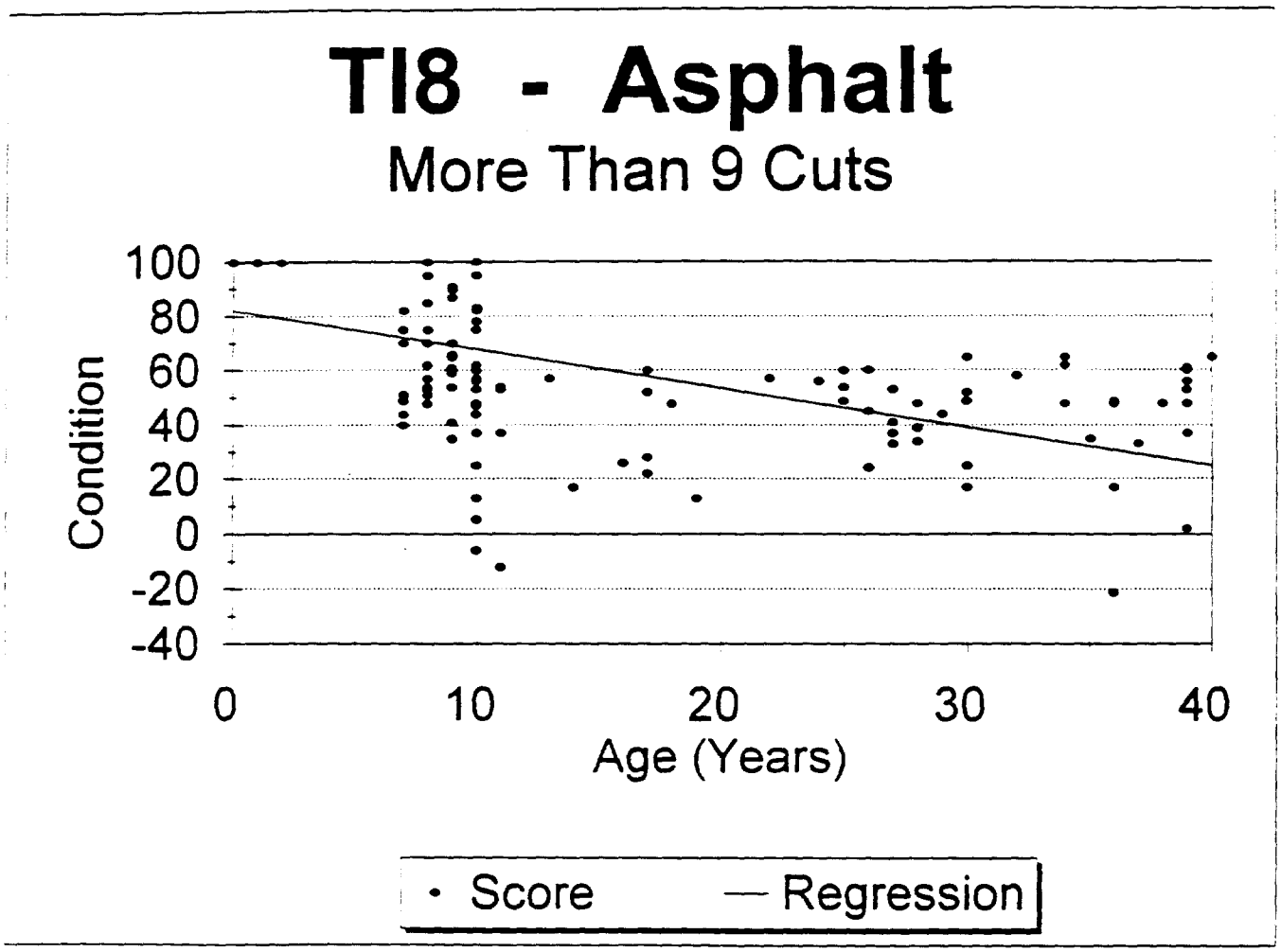

TI7 - Asphalt
Less Than 3 Cuts
100
80
60
40
20
0
-20
-40
Condition
0
10
20
30
40
Age (Years)
Score
Regression

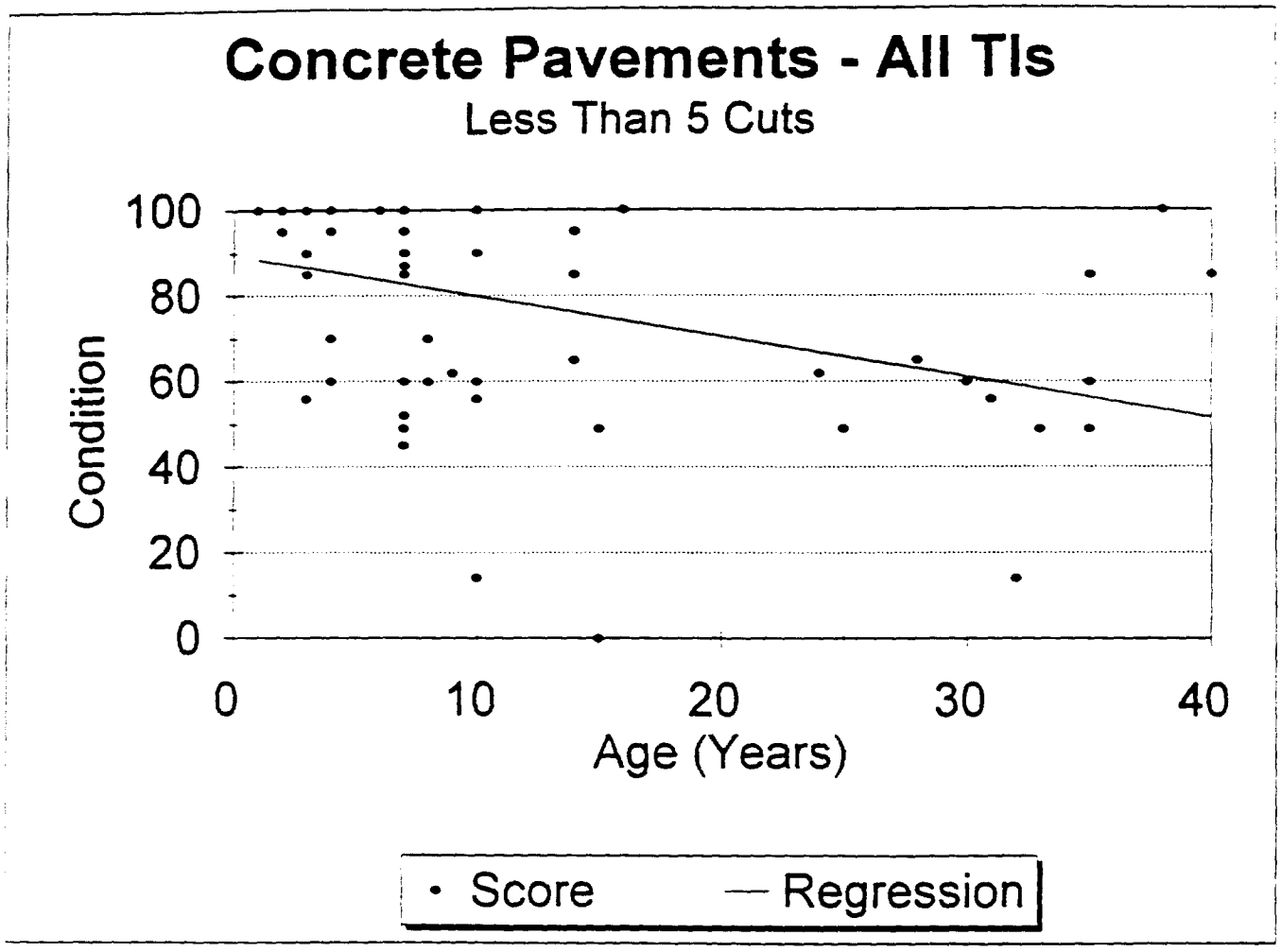

TI7 - Asphalt
3 To 9 Cuts
Condition
100
80
60
40
20
0
-20
-40
0
10
20
30
40
Age (Years)
Score
Regression

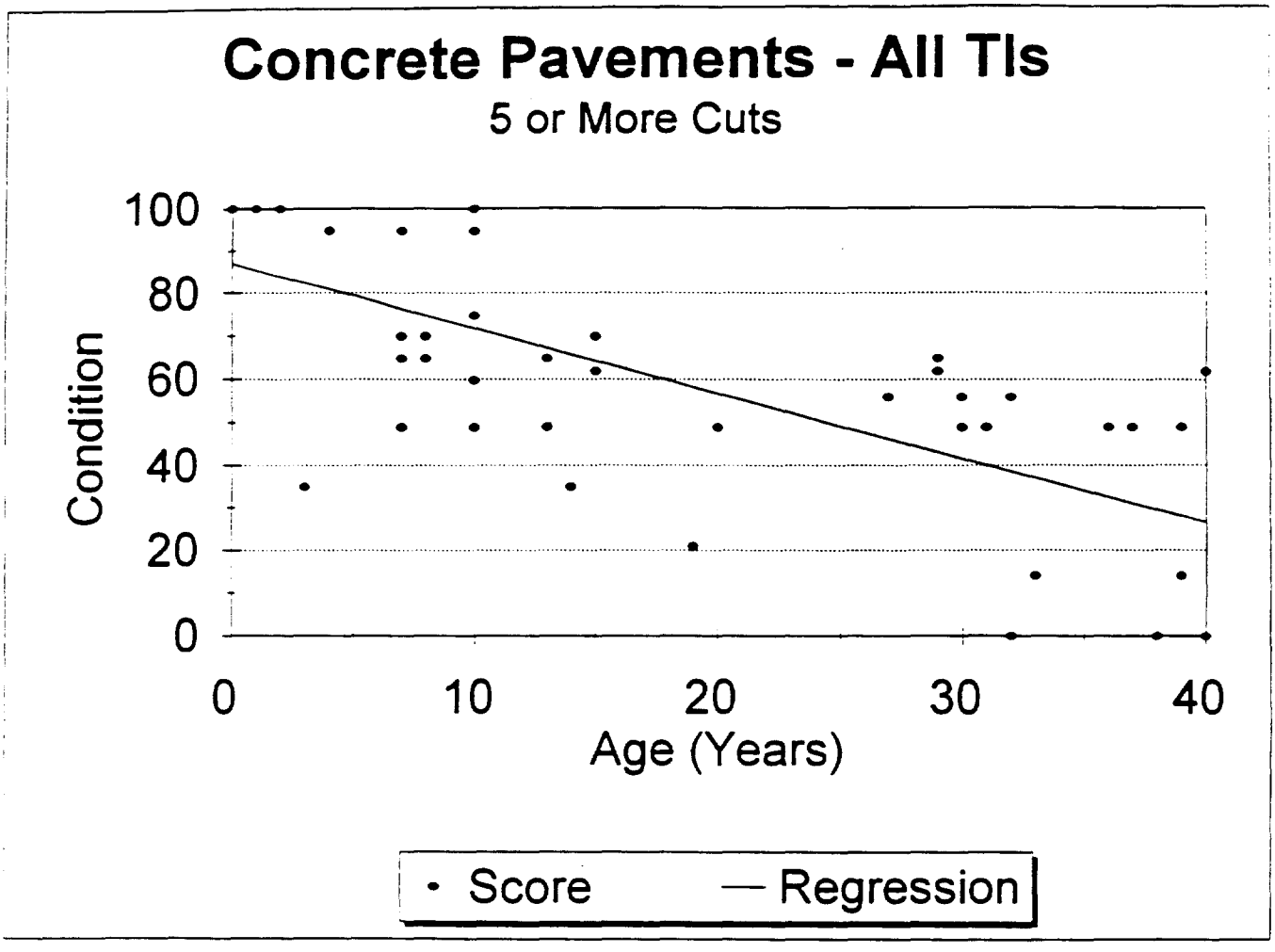

TI7 - Asphalt
More Than 9 Cuts
Condition
100
80
60
40
20
0
-20
-40
0
10
20
30
40
Age (Years)
Score
Regression

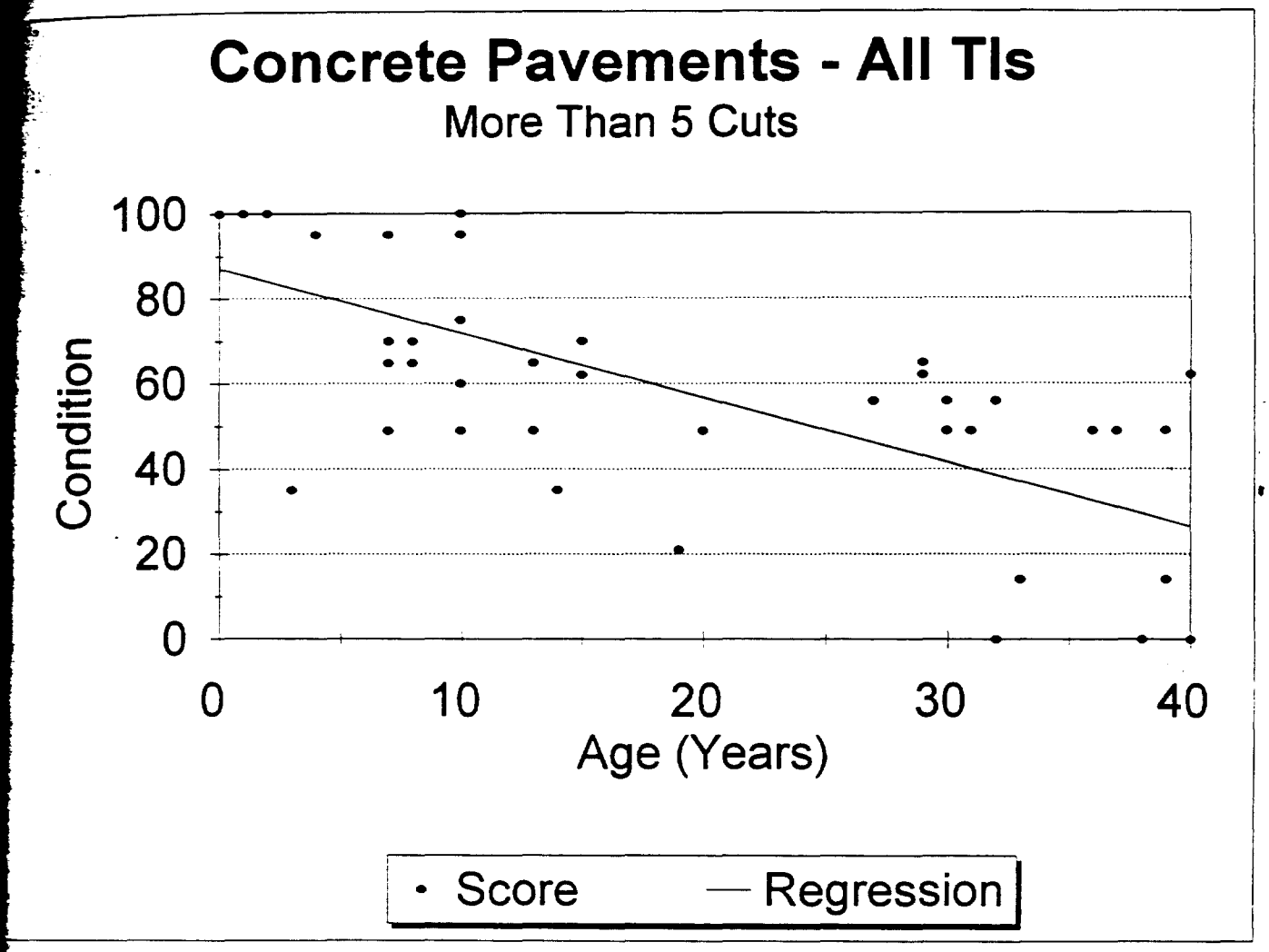

TI8 - Asphalt
Less Than 3 Cuts
100
80
60
40
20
0
-20
-40
Condition
0
10
20
30
40
Age (Years)
Score
Regression


TI8 - Asphalt
3 To 9 Cuts
Condition
100
80
60
40
20
0
-20
-40
0
10
20
30
40
Age (Years)
Score
Regression


TI8 - Asphalt
More Than 9 Cuts
Condition
100
80
60
40
20
0
-20
-40
0
10
20
30
40
Age (Years)
Score
Regression


Concrete Pavements - All TIs
Less Than 5 Cuts
Condition
100
80
60
40
20
0
0
10
20
30
40
Age (Years)
Score
Regression


Concrete Pavements - All TIs
5 or More Cuts
Condition
100
80
60
40
20
0
0
10
20
30
40
Age (Years)
Score
Regression


Concrete Pavements - All TIs
More Than 5 Cuts
100
80
60
40
20
0
Condition
0
10
20
30
40
Age (Years)
Score
Regression

IMS

INFRASTRUCTURE MANAGEMENT SERVICES

ESTIMATED PAVEMENT CUT SURCHARGE FEES

FOR THE

CITY OF ANAHEIM, CALIFORNIA

ARTERIAL HIGHWAY AND LOCAL STREETS

DECEMBER 9, 1994

PREPARED BY:
IMS, INFRASTRUCTURE MANAGEMENT SERVICES, INC.
1101 CALIFORNIA AVENUE, SUITE 100
CORONA, CALIFORNIA 91719
(909) 273-3420

INTRODUCTION

This report discusses the results of an investigation conducted by IMS, Infrastructure Management Services, Inc., for the City of Anaheim California. The purpose of this investigation is to estimate a pavement cut surcharge fee for City of Anaheim arterial highway and local streets, dependent upon pavement age. In order to develop an estimated pavement cut surcharge fee, the following variables need to be determined:

1. An estimate of the effect a pavement cut has on pavement life;

2. The area of pavement affected by a pavement cut;

3. Average pavement design life;

4. Average construction costs for arterial highway and local streets.

To estimate the effect a pavement cut has on pavement performance, the City of Anaheim specifically requested IMS to utilize the results of a study conducted by ERES, International, Inc., for the City of Phoenix, Arizona, "The Effects of Utility Cut Patching on Pavement Performance in Phoenix, Arizona", July 18, 1990. This report, hereinafter shall be referenced as the "Phoenix Study".

In the Phoenix Study 100 pavement sample units, 50 with, and 50 without pavement cuts were established. Each sample unit with a utility cut was matched with an adjacent sample unit which did not contain a utility cut. Each sample unit was 150 feet in length and as wide as the existing pavement width. Detailed pavement condition surveys were performed on the sample units with and without utility cuts.

Based on the comparison of the pavement condition data, the Phoenix Study estimates a pavement life reduction factor of 1.29 for pavement area affected by a utility cut for the City of Phoenix, AZ (ref. 1). Specifically at the request of the City of Anaheim, this pavement life reduction factor is assumed for pavement area affected by pavement cuts on both the arterial highway and local streets.

The Phoenix Study determined that a pavement cut affected the entire pavement width sampled. This is assumed to be the entire pavement width, as each sample unit selected in the Phoenix Study covered the entire pavement width (an average of 33 feet). Pavement cut surcharge fees are estimated based on an affected width of 33 feet.

An average pavement life of 20 years for newly constructed and/or rehabilitated arterial highway streets and an average pavement life of 35 years for newly constructed and/or rehabilitated local streets is assumed (ref. 2).

The average replacement value for an arterial highway street designed for a 20 year period is estimated to be $34.19 per square yard as calculated on page 3 of this report. The average replacement value for local streets, assuming an average design life of 35 years is estimated to be $20.00 per square yard as calculated on page 7 of this report.

Based on this data a pavement cut surcharge fee is estimated for both the arterial highway and local streets, dependent upon existing age of pavement.

ESTIMATED PAVEMENT CUT SURCHARGE FEE COST ANALYSIS FOR ARTERIAL HIGHWAY STREETS

The arterial highway system in the City of Anaheim, CA, consists of 184 centerline miles (ref. 2). This equates to approximately 6.2 million square yards of pavement area (ref. 3). The structural section replacement value is estimated to be 212 million dollars (ref. 4). This equates to an average structural section replacement value of $34.19 per square yard (SY) as calculated below:

$$Value/SY = \frac{Total\ Value}{Total\ Square\ Yards}$$

$$Value/SY = \frac{\$212,000,000}{6,200,000SY}$$

$$Value/SY = \$34.19/SY$$

Each arterial highway street construction project is designed for a 20 year period (ref. 2). Using a life cycle costing approach assuming no inflation, the value per square yard per year of pavement design life is calculated below:

$$Value/SY/Year = \frac{Value\ /\ SY}{Average\ Design\ Life\ in\ Years}$$

$$Value/SY/Year = \frac{\$34.19\ /\ SY}{20\ years}$$

$$Value/SY/Year = \$1.71/SY/Year$$

Based on a pavement life reduction factor of 1.29 due to pavement cuts, a pavement with 20 years of remaining design life, if cut, would have a reduction in life of 4.5 years as calculated below:

$$\textit{Life Reduction} = \textit{Remaining Life} - \frac{\textit{Remaining Life}}{\textit{Reduction Factor}}$$

$$\textit{Life Reduction} = 20\ \textit{Years} - \frac{20\ \textit{Years}}{1.29}$$

$$\textit{Life Reduction} = 20\ \textit{Years} - 15.5\ \textit{Years}$$

$$\textit{Life Reduction} = 4.5\ \textit{Years}$$

The value of this reduced life is equal to $7.70 per square yard of pavement area affected by the pavement cut as calculated below:

$$\textit{Value of Reduced Life} = \textit{Life Reduction} * \textit{Value/SY/Year}$$

$$\textit{Value of Reduced Life} = 4.5\ \textit{Years} * \$1.71/\textit{SY/Year}$$

$$\textit{Value of Reduced Life} = \$7.70/\textit{SY}$$

In order to estimate a pavement cut surcharge fee, an estimate of the pavement area affected by the pavement cut needs to be determined. The Phoenix Study assumed the entire street width up to a total width of 33 ft, is affected by a pavement utility cut (ref. 1). Based on an affected pavement width of 33 feet an estimated pavement cut surcharge fee (EPCSF) of $28.26 per lineal foot of pavement cut is estimated for a pavement less than one year old, as calculated below:

$$EPCSF\ per\ lineal\ ft = \frac{Value\ of\ Reduced\ Life * Area\ Affected}{1\ Lineal\ Foot}$$

and,

$$Area\ Affected = Pavement\ Width\ Affected * Lineal\ Feet\ Cut$$

so,

$$Area\ Affected = 33\ ft * 1\ ft$$

$$Area\ Affected = 33\ SF$$
$$= 3.67\ SY$$

Therefore,

$$EPCSF\ per\ lineal\ ft = \frac{\$7.70\ /\ SY * 3.67\ SY}{1\ Lineal\ Foot}$$

$$EPCSF\ per\ lineal\ ft = \$28.26$$

The following table lists estimated pavement cut surcharge fees for pavements from less than 1 year old up to less than 20 years old, in one year increments, based on the calculation methodology used above:

ESTIMATED PAVEMENT CUT SURCHARGE FEES FOR ARTERIAL HIGHWAY STREETS IN THE CITY OF ANAHEIM, CALIFORNIA BASED ON AN ASSUMED AFFECTED PAVEMENT WIDTH OF 33 FEET

Pavement Age (Years)	Life Reduction (Years)	Value of Reduced Life ($/SY)	EPCSF ($ per Lineal Foot)
<1	4.50	7.70	28.26
<2	4.27	7.30	26.79
<3	4.05	6.93	25.43
<4	3.82	6.53	23.97
<5	3.60	6.16	22.61
<6	3.37	5.76	21.14
<7	3.15	5.39	19.78
<8	2.92	4.99	18.31
<9	2.70	4.62	16.96
<10	2.47	4.22	15.49
<11	2.25	3.85	14.13
<12	2.02	3.45	12.66
<13	1.80	3.08	11.30
<14	1.57	2.68	9.84
<15	1.35	2.31	8.48
<16	1.12	1.92	7.05
<17	0.90	1.54	5.65
<18	0.67	1.15	4.22
<19	0.45	0.77	2.83
<20	0.22	0.38	1.39

ESTIMATED PAVEMENT CUT SURCHARGE FEE COST ANALYSIS FOR LOCAL STREETS

The local street system in the City of Anaheim, CA consists of approximately 416 centerline miles (ref. 2). This equates to approximately 8.8 million square yards (ref. 4). The structural section value is estimated to be 176 million dollars (ref. 4). This equates to an average structural section value of $20.00 per square yard (SY) as calculated below:

$$Value/SY = \frac{Total\ Value}{Total\ Square\ Yards}$$

$$Value/SY = \frac{\$176,000,000}{8,800,000SY}$$

$$Value/SY = \$20.00/SY$$

Each local street construction project is designed for a 20 year period, however, the Orange County Materials Lab states that many local streets exceed this design life and may perform for up to 35 years (ref. 2). Using a life cycle costing approach and no inflation, the value per square yard per year of pavement design life is calculated below:

$$Value/SY/Year = \frac{Value\ /\ SY}{Average\ Design\ Life\ in\ Years}$$

$$Value/SY/Year = \frac{\$20.00\ /\ SY}{35\ years}$$

$$Value/SY/Year = \$0.57/SY/Year$$

Based on a pavement life reduction factor of 1.29 due to pavement cuts, a pavement with 35 years of remaining design life, if cut, would have a reduction in life of 7.87 years as calculated below:

$$\textit{Life Reduction} = \textit{Remaining Life} - \frac{\textit{Remaining Life}}{\textit{Reduction Factor}}$$

$$\textit{Life Reduction} = 35\ \textit{Years} - \frac{35\ \textit{years}}{1.29}$$

$$\textit{Life Reduction} = 35\ \textit{Years} - 27.13\ \textit{Years}$$

$$\textit{Life Reduction} = 7.87\ \textit{Years}$$

The value of this reduced life is equal to $4.49 per square yard of pavement area affected by the pavement cut as calculated below:

$$\textit{Value of Reduced Life} = \textit{Life Reduction} * \textit{Value/SY/Year}$$

$$\textit{Value of Reduced Life} = 7.87\ \textit{Years} * \$0.57/\textit{SY/Year}$$

$$\textit{Value of Reduced Life} \quad \$4.49/\textit{SY}$$

In order to estimate a pavement cut surcharge fee, an estimate of the pavement area affected by the pavement cut needs to be determined. The Phoenix Study assumed the entire street width, up to a total width of 33 ft is affected by a pavement utility cut (ref. 1). Based on an assumed affected pavement width of 33 feet an estimated pavement cut surcharge fee

(EPCSF) of $16.48 per lineal foot of pavement cut is estimated for a pavement less than one year old as calculated below:

$$EPCSF\ per\ lineal\ ft = \frac{Value\ of\ Reduced\ Life * Area\ Affected}{1\ Lineal\ Foot}$$

and,

$$Area\ Affected = Pavement\ Width\ Effected * Lineal\ Feet\ Cut$$

so,

$$Area\ Affected = 33\ ft * 1\ ft$$

$$Area\ Affected = 33\ SF$$
$$= 3.67\ SY$$

Therefore,

$$EPCSF\ per\ lineal\ ft = \frac{\$4.49\ /\ SY * 3.67\ SY}{1\ Lineal\ Foot}$$

$$EPCSF\ per\ lineal\ ft = \$16.48$$

The following table lists estimated pavement cut surcharge fees for pavements from less than 1 year old up to less than 35 years old, in one year increments, based on the calculation methodology used above:

ESTIMATED PAVEMENT CUT SURCHARGE FEES FOR LOCAL STREETS IN THE CITY OF ANAHEIM, CALIFORNIA BASED ON AN ASSUMED AFFECTED PAVEMENT WIDTH OF 33 FEET

Pavement Age (Years)	Life Reduction (Years)	Value of Reduced Life ($/SY)	EPCSF ($ per Lineal Foot)
<1	7.87	4.49	16.48
<2	7.64	4.35	15.96
<3	7.42	4.23	15.52
<4	7.20	4.10	15.05
<5	6.97	3.97	14.57
<6	6.74	3.84	14.09
<7	6.52	3.72	13.65
<8	6.29	3.59	13.18
<9	6.07	3.46	12.70
<10	5.84	3.33	12.22
<11	5.62	3.20	11.74
<12	5.40	3.08	11.30
<13	5.17	2.95	10.83
<14	4.95	2.82	10.35
<15	4.72	2.69	9.87
<16	4.50	2.57	9.43
<17	4.27	2.43	8.92
<18	4.05	2.31	8.48
<19	3.82	2.18	8.00
<20	3.60	2.05	7.52
<21	3.37	1.92	7.05

<22	3.15	1.80	6.61
<23	2.92	1.66	6.09
<24	2.70	1.54	5.65
<25	2.47	1.41	5.17
<26	2.25	1.28	4.70
<27	2.02	1.15	4.22
<28	1.80	1.03	3.78
<29	1.57	0.89	3.27
<30	1.35	0.77	2.83
<31	1.12	0.64	2.35
<32	0.90	0.51	1.87
<33	0.67	0.38	1.39
<34	0.45	0.26	0.95
<35	0.22	0.13	0.48

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